

Geologic Resource Evaluation Scoping Summary Tonto National Monument, Arizona

Geologic Resources Division
National Park Service
U.S. Department of the Interior



The goal of the Geologic Resource Evaluation (GRE) Program is to provide each “natural area” park with a digital geologic map and a geologic resource evaluation report. As a means of obtaining this goal, the NPS Geologic Resources Division (GRD) coordinates scoping meetings that bring together park staff and local geologic experts. The scoping process includes an evaluation of the adequacy of existing geologic maps and a discussion of park-specific geologic management issues. When possible, a site visit with local experts is also part of the scoping process. Outcomes are a scoping summary (this report), and ultimately a digital geologic map and accompanying geologic resource evaluation report. Along with the completed digital map, this scoping summary will serve as the starting point for writing and compiling the final GRE report for Tonto National Monument.

The National Park Service held a GRE scoping meeting near Roosevelt, Arizona, for Tonto National Monument on Tuesday, May 9, 2006. Before the “formal” meeting, Brad Traver (superintendent, Tonto National Monument) and Duane Hubbard (resource program manager, Tonto National Monument) led a short field trip to the lower cliff dwelling. While hiking, participants passed through various rock units: Barnes conglomerate (cobbles in wash), Gila conglomerate (formed basins during faulting and uplift), and the Dripping Spring quartzite, in which the caves formed and the Salado people built their cliff dwellings.

Discussion during the meeting addressed geologic mapping coverage and needs, distinctive geologic processes and features, resource management issues related to these features and processes, and potential monitoring and research needs. Participants at the meeting included NPS staff from the monument, Geologic Resources Division, Sonoran Desert Network, and Southern Arizona Office; and cooperators from the U.S. Geological Survey, Arizona Geological Survey, and Colorado State University (table 1). Melanie Ransmeier (GRD) facilitated the discussion of map coverage, and Lisa Norby (GRD) led the discussion regarding geologic processes and features at the monument.

Table 1. Scoping Session Participants

Name	Affiliation	Phone	E-Mail
Andy Hubbard	NPS Sonoran Desert Network (network coordinator)	520-546-1607 x1	andy_hubbard@nps.gov
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Melanie Ransmeier	NPS Geologic Resources Division (GIS specialist)	303-969-2315	melanie_ransmeier@nps.gov
Jon Spencer	Arizona Geological Survey (geologist)	520-770-3500	jspencer@azgs.az.gov
Brad Traver	Tonto National Monument (superintendent)	928-467-2241	brad_traver@nps.gov
Laurie Wirt	U.S. Geological Survey (geologist)	303-236-2492	lwirt@usgs.gov

Status of Scoping and Products

As of May 2006, the NPS Geologic Resources Division had completed the scoping process for 169 of 270 “natural resource” parks. Staff and partners of the GRE Program have completed digital maps for 69 parks. These compiled geologic maps are available for download from the NR-GIS Metadata and Data Store at <http://science.nature.nps.gov/nrdata>. The U.S. Geological Survey, various state geological surveys, and investigators at academic institutions are in the process of preparing mapping products for 49 additional parks. Writers have completed 22 GRE reports with 60 additional reports in progress.

Park and Geologic Setting

The Congress of the United States proclaimed Tonto National Monument on December 19, 1907, to preserve two cliff dwellings (AD 1300–1500) and the ecosystems of the surrounding Sonoran Desert. The area was transferred from the USDA Forest Service to the National Park Service in 1933, with a boundary change in 1937.

For 300 years, a culture called Salado by 1930s archaeologists lived within the Tonto Basin, surviving and adapting to the arid environment. The peak of occupation in the area was AD 1250. The cliff dwellings—built in shallow caves that are perched more than a thousand feet above the river valley—are representative of the final phase of occupation in this area. Considered one of the most rugged areas in the state of Arizona, slopes in the monument range from 2% to 90%. Elevation at Tonto National Monument ranges from 2,300 to 4,000 feet. Most of this thousand-foot rise occurs within a distance of three-quarters of a mile.

The river valley, once a thriving settlement with farm fields and stone dwellings, is now covered by Theodore Roosevelt Lake. The reservoir, entirely within Tonto National Forest, was created in 1911. The surrounding mountains, composed of uplifted sedimentary layers, are continually being shaped through erosion and weathering. From the valley floor, the topography rises nearly 2,000 feet to the mountain tops, encompassing open areas, rock shelters, canyons, and washes.

Weathering and erosional processes created shallow overhangs in the Precambrian Dripping Spring quartzite. These caves protected the cliff dwellings and their inhabitants from the weather and possibly from intruders. Sedimentary and igneous rocks in the area provided the people of the Salado culture with the raw material for shaping tools and the building materials for dwellings and terraces. For example, blocks of the Gila conglomerate, an ancient alluvial fan deposit, were worked into the structure of the cliff dwellings. Cemented gravel, clay, and silica form this distinctive rock unit.

Tonto Basin is one of a series of large intermontane basins filled with debris that eroded from adjacent mountain ranges. Sedimentary layers were deposited as the land was repeatedly covered with sea water. Interbedded with these marine sediments is terrestrial debris eroded from the mountains. Some rocks display mud cracks, formed when sediments dried out, and ripple marks, formed in shallow water. The present-day mountains were created through cycles of deposition, uplift, and erosion. As the most recent uplift progressed, the Salt River cut valleys and canyons and carried debris to the surrounding lowlands. The coarsest materials were deposited close to the mountains, while finer sediments were transported out into the center of the basin.

Strata in the monument are composed of the Precambrian Apache Group (see fig. 1). The entire Precambrian section of the Apache Group is exposed in Tonto National Monument (from oldest to youngest): Pioneer shale, Dripping Spring quartzite, Mescal limestone, and basalt. The alcoves that house the cliff dwellings are part of the Dripping Spring quartzite, which consists primarily of siltstone with some sandstone. Geologists divide the Dripping Spring quartzite into three members: Barnes conglomerate, middle member, and upper member. The cliff dwellings are in the middle member. Natural weathering processes formed the caves, probably starting between 50,000 and 400,000 years ago as thin layers of siltstone broke loose and fell from the cave's ceiling and walls. Spalling of rocks in the alcoves is still occurring today. Asbestos mining in the Mescal limestone has occurred northeast of the monument. About 1.1 billion years ago, the Apache Group was intruded by a diabase composed primarily of plagioclase and pyroxene, with some pegmatite. As the diabase injected along bedding planes, it inflated the Apache Group by 20% to 100%.

More recent geologic events include geomorphic changes to the drainage system about 14 million years ago and a huge, volcanic eruption in the area that is now the Superstition Mountains (southwest of the monument) about 18 million years ago. An ash layer, the Apache Leap tuff, records this event.

Some Geological Features of the Tonto National Monument, Gila County, Arizona, by Robert B. Raup Jr. highlights rocks and other interesting geologic features exposed at the monument, many of which are along the trail to the lower ruins. These features include the following: cross stratification, ripple marks, current marks, shrinkage cracks, stromatolites (see “Paleontological Resources” section), stylolites, limonite, fractures, and calcium carbonate deposits (e.g., calcite, caliche, stalactites, and stalagmites).

ERA	PERIOD	UNIT		THICKNESS (METERS)
PALEOZOIC	DEVONIAN	Martin Formation		10-120
		Abrigo Formation		0-255
	CAMBRIAN	Bolsa Quartzite		0-145
MIDDLE PROTEROZOIC		Unconformity		
		Diabase		
		Intrusive contact		
		Troy Quartzite	Quartzite member	0-150
			Chediski Sandstone Member	0-210
			Arkose member	0-140
		Unconformity		0-365
		APACHE GROUP	Basalt	0-115
			Unconformity	
			Argillite member	0-30
			Unconformity	
			Basalt	0-35
			Unconformity	
			Mescal Limestone	12-40
			Lower member	45-82
			Unconformity	
			Upper member	55-130
			Middle member	40-110
			Barnes Conglomerate Member	0-18
			Unconformity	140-215
			Pioneer Shale	45-155
			Scanlan Conglomerate Member	0-15
EARLY PROTEROZOIC		Unconformity		
		Granitic rocks		
		Intrusive contact		
		Sedimentary and volcanic rocks, locally foliated		

Figure 1. Geologic stratigraphic chart in the vicinity of Tonto National Monument, Arizona. All of the rocks in the Apache Group are exposed in the monument. *Source:* Presentation by Jon Spencer (Arizona Geological Survey).

Geologic Maps for Tonto National Monument

During the scoping session on May 9, 2006, Melanie Ransmeier (GRD) showed some of the main features of the NPS GRE Geology-GIS Geodatabase Data Model—the digital geologic map model used by the GRE Program. The model reproduces all aspects of a paper map, including notes, legend, and cross sections, with the added benefit of being GIS compatible. Staff members digitize maps or convert digital data using ESRI ArcMap software. Digital data are provided in each of the following three formats: geodatabase, shapefile, and coverage. Layer files (legends), FGDC-compliant metadata, and a Windows HelpFile that captures ancillary map data, are also part of the final dataset.

Parks in Inventory and Monitoring Networks have identified 7.5-minute “quadrangles of interest.” In general, digital geologic data from 7.5-minute quadrangles (scale 1:24,000) suit the purpose of geologic resource evaluations. The geologic features mapped at this scale are equivalent to the width of a one-lane road. Quadrangles of interest are used as a starting point for discussion in determining the components of the final digital geologic map for a park. A recent policy change for the GRE Program, however, excludes from potential digitizing any quadrangles that do not include a portion of the park. This summary attempts to outline an action plan that incorporates this new policy while providing a digital map useful for resource management.

Map coverage for Tonto National Monument consists of four quadrangles of interest (scale 1:24,000): Theodore Roosevelt Dam, Windy Hill, Pinyon Mountain, and Two Bar Mountain, which are situated on the Theodore Roosevelt Lake 30' × 60' sheet (see fig. 1 and table 2).

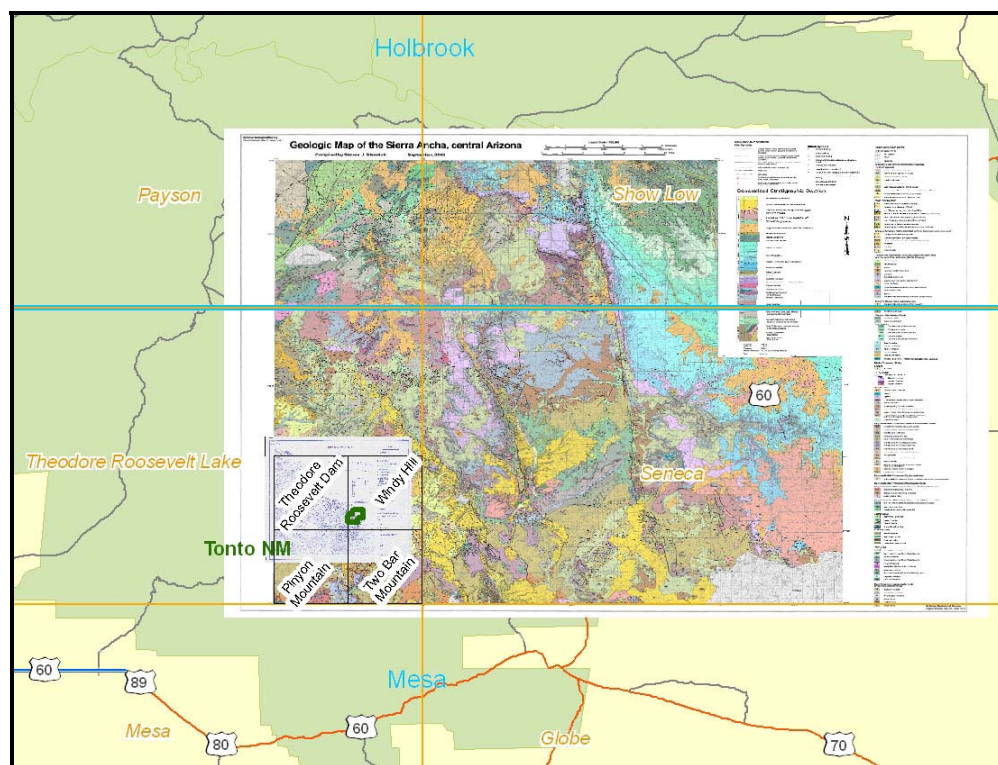


Figure 1. Quadrangles of interest for Tonto National Monument, Arizona. The 7.5-minute quadrangles (scale 1:24,000) are labeled in black; names in yellow indicate 30-minute by 60-minute quadrangles (scale 1:100,000). Names in blue indicate 1-degree by 2-degree sheets (scale 1:250,000). Green outline indicates the boundary of the monument. The smaller blue-line map shown in the figure is Spencer and Richard (1999). It covers most of the Theodore Roosevelt Dam quadrangle and parts of the Pinyon Mountain, Two Bar Mountain, and Windy Hill quadrangles (scale 1:24,000), including all but the extreme northeast portion of the monument. The larger, color geologic map shown in the figure is Skotnicki (2002). It is a geologic map of the Sierra Ancha of central Arizona (scale 1:100,000).

Table 2 outlines the GRE plan for providing geologic data for Tonto National Monument. In short, GRE staff will provide digital data for the Theodore Roosevelt Dam and Windy Hill quadrangles. However, Spencer and Richard (1999) and Spencer and others (1999) (see table 2) provide only bedrock geology, and park and network staffs need surficial data for monitoring and resource management purposes (e.g., vegetation and archaeological sites). In particular, they need ages of various surfaces (e.g., fans, terraces, and other landforms). Participants in the scoping meeting agreed that surficial data for the monument and the immediate surrounding area is most critical for resource management.

On May 10, 2006, GRE staff discussed the possibility of mapping the surficial geology at Tonto National Monument with Phil Pearthree (geologist, Arizona Geological Survey, 520-770-3500, phil.pearthree@azgs.az.gov); he expressed willingness to assist the National Park Service in this endeavor. GRE staff needs to follow up with the Arizona Geological Survey and park staff members to design an appropriate mapping proposal and project for Tonto National Monument.

Table 2. GRE Mapping Plan for Tonto National Monument

Quadrangles	GMAP ¹	Citation	Scale	Format	Assessment	GRE Action
Theodore Roosevelt Dam; parts of Pinyon Mountain, Two Bar Mountain, and Windy Hill	7493	Spencer, J., and Richard, S., 1999, Geologic map of the Theodore Roosevelt Dam area, Arizona: Arizona Geological Survey Open-File Report OFR 99-06, scale 1:24,000.	1:24,000	Paper	Though this map is smaller in extent than GMAP 7492 (Sierra Ancha, scale 1:100,000), it provides the most detailed geology known in the area. Provides bedrock geology only	Digitize this map.
Windy Hill	74430	Spencer, J.E., Richard, S.M., Ferguson, C.A., and Gilbert, W.G., 1999, Preliminary bedrock geologic map and cross sections of the Windy Hill 7.5' quadrangle, Gila County, Arizona: Arizona Geological Survey Open-File Report OFR 99-12, scale 1:24,000.	1:24,000	Paper	Provides bedrock geology only	Digitize this map.
Theodore Roosevelt Dam, Windy Hill, Pinyon Mountain, Two Bar Mountain	7492	Skotnicki, S.J., 2002, Geologic map of the Sierra Ancha, central Arizona: Arizona Geological Survey Digital Geologic Map DGM-24, scale 1:100,000.	1:100,000	Digital	Useful for resource management of regional area	None Note: Arizona Geological Survey will provide Tonto staff with digital data.

¹GMAP numbers are identification codes used in the GRE database.

Geologic Features, Processes, and Issues at Tonto National Monument

The scoping session for Tonto National Monument provided the opportunity to develop a list of geologic features and processes, which will be further explained in the final GRE report. During the meeting, park staff prioritized the issues as follows:

1. Fluvial processes (the effect of flowing water on resources)
2. Cave resources
3. Hillslope processes, in particular rockfall hazards

In addition (and related to geology), the longevity of the park's water well is a concern for park managers. The water table has dropped during the present drought, which could affect well productivity. The National

Park Service drilled this well in 1963 at the juncture of two faults; it provides the water for park administrative needs. A natural spring used to be located where the well is now; it no longer flows to the surface. One other spring, Cave Canyon spring, occurs in the riparian area of the monument.

Cave Features

The caves that form in the Dripping Spring quartzite (middle member) house the Salado cliff dwellings. Most of the caves appear to be the “alcove type;” however, neither the National Park Service nor cooperators have conducted a thorough inventory of the cave resources in the monument. A few talus caves may occur where large blocks of rock have accumulated, though this has not been inventoried. These cavities within the talus slopes may contain archaeological sites.

During years with high levels of precipitation, water drips through fractures into the caves. In the past, the Salado collected this water in cisterns. The process of spalling in the caves is associated with these wet periods. Some rocks have fallen while staff and visitors have been in the cliff dwellings, resulting in a minor safety hazard.

A significant resource management question is whether retaining walls constructed since 1950 are altering the natural drainage and damaging archaeological structures. Water may be flowing behind the retaining walls and eroding the prehistoric structures behind them. A study using ground penetrating radar by a contractor out of Tucson will investigate this in 2007. Mitigation (i.e., drilling or unclogging “weep holes” in the retaining walls) may be possible. Some of the older walls (1950s vintage) are gunite; others are masonry. Laurie Wirt (U.S. Geological Survey–Denver) thinks the walls could be retrofitted with weep holes, if necessary.

The upper and lower cliff dwellings serve as bat habitat, which does not seem to be adversely affecting the Salado structures. However, birds and rodents appear to be accelerating erosion (see Rutenbeck, 1993). Bee hives also occur in the vicinity of the dwellings; these are a concern for visitor safety, not archaeological preservation.

Hillslope Processes

Steep slopes are often the sites of archaeological structures, possibly serving as a defense against intruders. Hillslope processes are common on such slopes; for instance, landslides and rockfalls have occurred on the opposite side of the valley from the upper cliff dwelling (northeast side of Cave Canyon Wash).

To accommodate visitation to the cliff dwellings, the National Park Service built a parking lot and a trail leading to the lower cliff dwelling. The parking lot was built on alluvium. In winter 2005 (a wet year), the “fill” in the parking lot dropped 8 inches, and the lower trail also experienced erosion. Rockfall along the trails to both the lower and upper cliff dwellings are a potential safety hazard. The trail to the lower cliff dwelling is of particular concern for two reasons: (1) the retaining walls increase erosion along this trail and (2) an obvious overhang, under which visitors walk, occurs just below the ruin.

In 1978 heavy rainfall caused concern about the potential for failure of the cave roof, resulting in damage to the dwellings. Since this time, various reports and memorandums, in particular those by Todd Rutenbeck (structural engineer with the NPS Western Archeological Center in Tucson, Arizona, and later the Bureau of Reclamation), have resulted in monitoring of the upper and lower cave dwellings. Duane Hubbard (resource program manager, Tonto National Monument) has copies of these reports (Rutenbeck 1978, 1980, 1985, and 1993). Recommendations include (1) defining and minimizing the risk such as monitoring movement, (2) wearing hard hats in the dwellings, (3) diverting water, (4) removing loose rock fragments, and (5) minimizing the time people spend in the most hazardous areas (Rutenbeck, 1980). Results of monitoring show no evidence of progressive movement leading to failure. Most movements are very small and appear to be seasonal (Rutenbeck, 1985). Todd Rutenbeck states, “The caves and ruins are safer than they appear, but

are not completely without hazards.” In particular, instant failures or movements are possible during seismic events or period of high rainfall (Rutenbeck, 1985).

Eolian (Windblown) Features and Processes

Colleen Filippone, hydrologist for the NPS Intermountain Region in Tucson, Arizona (520-546-1607 x. 3), is monitoring wind erosion at Tonto. Monitoring revealed some wind activity in the northeastern flat area of the monument. Wind erosion probably caused pockets of soil erosion there.

Fluvial Features and Processes and Water Erosion

Flash flooding in Cave Canyon is an issue for resource management because the wash is not a stable stream channel and slopes can fail during flooding events. A question is whether human perturbations are exacerbating changes to stream channel morphology. For instance, is grazing on USDA Forest Service (USDA-FS) land in the upper watershed a cause? Stream-bank erosion affects riparian habitat and causes some damage to the monument’s infrastructure, for example, to roads when culverts get clogged. Park staff is concerned about fluvial erosion affecting the well and storage tank: a 50,000-gallon water tank and park-maintained road are situated next to the creek. Both of these could be damaged or destroyed during a flood. In addition, soil crusts are stabilizing banks and terraces along the wash, which a major flood could damage.

The Intermountain Region is monitoring stream channel morphology at Tonto National Monument (contact: Colleen Filippone, hydrologist, 520-546-1607 x. 3). Cave Canyon spring feeds into Cave Canyon Wash. This natural spring was historically dammed and used to be the water source for the monument.

With respect to soil erosion, the Natural Resource Conservation Service (NRCS) completed a preliminary soil survey in 1994. Park staff would be interested in getting expertise that would provide greater detail than the NRCS report, in particular erodibility of sites with respect to archaeological resources, ground cover, and past grazing impacts. Duane Hubbard expressed interest in getting technical assistance from Pete Biggam, NPS soil scientist (D. Hubbard, Tonto National Monument, telephone conversation, June 27, 2006).

Seismic Features and Processes

Tonto National Monument is situated in an area of low seismic hazard potential. Nevertheless, park management has a 25-year record of data from a series of gauges that measured cracks in archaeological structures. Park staff is no longer monitoring changes in cracks because the 25-year record shows minimal movement. Anthropogenic seismicity is a concern, however. Overflights cause vibrations, but park managers do not have the legislative authority to prohibit overflights, though they do try to discourage hovering near the ruins.

Paleontological Resources

Raup (1959) reports the Precambrian stromatolites from the Mescal limestone. Stromatolites are typically dome- or plate-shaped structures produced by sediment trapping, binding, or precipitation as a result of the growth of microorganisms, particularly cyanobacteria. In addition, Skotnicki (2001)—a PhD thesis from Arizona State University—discusses Proterozoic microbial life preserved in this formation.

Disturbed Lands

In many areas, National Park System units represent the last vestiges of once vast and undisturbed ecosystems. Yet, according the NPS Geologic Resources Division’s Web site at <http://www2.nature.nps.gov/geology/distlands/>, modern human activities, including abandoned roads, dams, canals, railroads, grazed areas, campgrounds, mines, and other abandoned sites, have disturbed more than 315,000 acres in 195 parks. Some of these features may be of historical significance, but most are not in keeping with the mandate of the National Park Service, “to conserve the scenery and the natural and historic objects and the wildlife therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations.” (16 U.S.C. 1 et seq.)

Lands disturbed by human activity often cause unwanted and long-lasting problems that affect other resources. Many of these disturbances obliterate soil profiles, exacerbate the invasion of exotic plants, result in contamination of water and soil, and cause erosion and sedimentation. These damages, in turn, frequently impair the quality of habitats, disrupt ecosystem functions, and cause problems for managing areas as wild lands. Disturbed lands at Tonto National Monument include mineral development in the vicinity of the monument and grazing.

Grazing

Grazing on USDA-FS land upstream of the monument, though limited in recent years, has occurred for the past century. Grazing may have accelerated erosion along the slopes, and caused changes in vegetation and soil compaction. Participants at the scoping meeting suggested that short-interval prescribed burning to control mesquite on USDA-FS land may also have contributed to erosion and sedimentation downstream in the monument. However, this suggestions needs to be verified. In the past, cows trespassing in the monument got into archaeological sites, causing damage. Grazing, allowed in Tonto National Monument until the 1970s, reduced vegetation, damaged archaeological sites, and compacted soils. Another disturbance related to cattle grazing is the construction of a stock pond, which may have contributed to the survival of mesquite habitat in the valley below the cliff dwellings.

Mineral Development

Though current uranium mining and previous asbestos mining have occurred in the vicinity of Tonto National Monument, no mines occur within its boundaries. Pinto and Pinal creeks have transported tailings from local copper mines into Theodore Roosevelt Lake; Ham (1995) characterized these lake sediments. In addition, the Forest Service has a large borrow pit for sand and gravel on USDA-FS land east of the monument; this pit yields decomposed granite, which park maintenance staff uses.

Unique Geologic Features at Tonto National Monument

Unique geologic features may include features mentioned in a park's enabling legislation, features of widespread geologic importance, geologic resources of interest to visitors, or geologic features worthy of interpretation. Type localities and age dates are also considered unique geologic features.

At Tonto National Monument unique features (in addition to stromatolites, see "Paleontological Resources") include biological soil crusts and a "window" in the Dripping Spring quartzite that faces Cottonwood Canyon on the west side of the monument. Biological soil crusts are impressive for the stabilization they provide; they hold nearly vertical stream channel cuts in place. The formation of biological crusts in these drainages could be geologically controlled. In addition, these crusts appear to be rich in cyanobacteria, which add nitrogen to the soil. According to Andy Hubbard (network coordinator, Sonoran Desert Network) who conducted a preliminary examination of the crusts in the monument with Jayne Belnap (U.S. Geological Survey), both the diversity and productivity of these soil crusts are outstanding.

As mentioned in the "Geologic Maps for Tonto National Monument" section, determining the ages of land surfaces such as alluvial fans and terraces is important for gaining a better understanding of past human occupation in the area. Participants mentioned the possibility of using comogenic dating methods (e.g., beryllium-10) for obtaining ages of the surfaces. In addition, valley fill contains ash beds that could be dated.

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